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three condensations are 44.2, 51.5 and 58.7 miles per second; or, expressed in astronomical units, the mean distance of the Earth from the Sun being the unit of distance, and 58.13244 mean solar days the unit of time, they are, respectively, 2.389, 2.783 and 3.171.

The theoretical velocity for tails of the first type, for the position of the second condensation, is 2.27, instead of 2.78 as given above.

As has been previously stated, the second condensation was more determinate than the others, and its velocity is accordingly entitled to a greater degree of confidence. Its velocity may be somewhat too small. I do not think it is too large.

Dr. BREDICHIN, assuming the velocity I sent him — 400,000 miles an hour, — has computed the corresponding value of $1-\mu$, and obtained 247. In this μ is the effective acceleration of the Sun at the unit of distance. From his previous investigations, the definitive value* of $1-\mu$, for tails of the first type — which are supposed to consist of hydrogen — is 17.5.

With the same data that he used, but with the velocity given in this paper, I have found $1-\mu$ to be 36, or about twice as great as for the first type. According to Dr. BREDICHIN'S theory, this value of $1-\mu$ corresponds to a substance having a molecular weight only half as great as hydrogen.

June 22, 1895.

DESCRIPTION OF A NEW CASSEGRAINIAN TELESCOPE, EQUATORIALLY MOUNTED, HAVING AN EQUIVALENT FOCAL LENGTH OF TWO HUNDRED AND FIFTY FEET.

BY J. M. SCHAEBERLE.

For obtaining the best astronomical photographs, the reflecting telescope should possess a great advantage over the refractor, for only by reflection can all the rays — both visible and invisible — of the spectrum, coming from a celestial object, be brought to a common focus.

With one or two exceptions, but little has been done in the

* *Annales de l'Observatoire de Moscou*, 2d Series, Vol. I, 1, page 22.

photography of celestial objects having very small angular dimensions.

The photographs of *Jupiter*, taken with the great refractor of the LICK Observatory, and those of *Saturn*, taken with the Paris refractor, are of real merit, and probably represent the best results in this line so far obtained by astronomers.

In photographs taken with the refractor, the minuteness of the planetary (and similar) focal images, and the inherent defects of these images, due to the dispersion of the rays, will always tend to obliterate the details seen visually. These optical defects are still further increased when such focal images are enlarged in the telescope by means of lenses. For the enlarged image, the same defects, though in a much less degree, will exist when the focal image is formed by a reflecting surface and the enlargement secured by means of lenses.

Some preliminary experiments during the past winter and spring made it evident that there were no good reasons why the enlarged focal image should not be wholly made by reflection, thus doing away with the inevitable dispersion of the rays caused by the use of lenses.

In the Cassegrainian (or Gregorian) form of telescopes, the size of the focal image after reflection from the secondary mirror can be increased to any desired linear dimensions by simply bringing the secondary mirror to the required surface curvature.

During the early days of my connection with the University of Michigan, I ground, polished, and figured a number of disks of glass, to be used as parabolic reflectors. Three of these are at present at the LICK Observatory. They have the following constants:

Aperture.	Focal Length.
8 inches.	6 feet.
12 "	4 "
18 "	12 "

All of these were mounted, at Ann Arbor, as Newtonians, on home-made equatorials; but owing to the great amount of teaching in the University of Michigan, my time was so fully occupied that no systematic work was possible with these instruments.

In order to take full advantage of this method of securing very large celestial images to be photographed in the telescope

without the use of lenses, the following conditions, at least, must be fulfilled:

1. The reflecting surfaces must be of unusually perfect curvature.

2. The mounting must be equatorial, very rigid, and the form either Cassegrainian or Gregorian.

3. The driving-clock must have no short periodic variations of rate.

The eighteen-inch reflector was originally intended to be used as a Newtonian. To adapt it to the Cassegrainian form, it was necessary to cut out the central portions of the mirror. While there was considerable danger that the figure of the mirror might be altered, I nevertheless took the risk, as there was but little probability that the reflector would be used as a Newtonian at the LICK Observatory. Accordingly, a concentric disk of the reflector, something over four inches in diameter, was cut directly from the central area of the mirror by means of a cylinder of thin sheet-copper, the saw-toothed grinding edge of which was kept supplied with emery and water. The tool was held in a foot-lathe chuck, revolving several hundred turns per minute, while the reflector was vertically mounted in a stationary frame, which could be pressed against the grinding tool.

An immediate test of the mirror after the removal of the central disk showed that no sensible alteration of the figure had taken place.

As the only practical way to bring the secondary mirror to the proper figure is by actual trial on celestial objects, it was essential, first of all, to have the large mirror mounted equatorially. In designing the form of mounting, great rigidity of all the parts was constantly kept in view.

The thirteen-foot tube is made of half-inch boards, bound with iron. It is supported below its center (by two opposite bearings, which form the declination axis,) in a rectangular iron frame, or cradle, so that it can swing through an arc of 140°. This cradle, in turn, is supported by two other bearings, which form the hour-axis of the telescope after the plan of the old English mountings.

The upper pivot of the hour-axis is four inches in diameter, and rests in a brass Y fastened to the top of a rigid triangular wooden frame, which is inclined to the horizon at an angle equal to the co-latitude of the place. The lower pivot is only

three-quarters of an inch in diameter. It revolves in a steel bearing, and abuts against a brass plate, which takes up the end thrust.

Near the upper end of the tube are two opposite bearings, in which swings an iron fork, the handle of which passes through and can be clamped (in Declination) to a collar in the hour-axis at the lower interior side of the cradle.

The diurnal motion is secured by means of a governing-clock, acting on a 15° sector of nearly ten feet radius. This sector is fastened to the outer end of a trussed iron frame, one of whose legs encircles the upper pivot of the hour-axis, while the lower pivot of the hour-axis passes through the lower leg of this sector-frame. The tube is clamped (in Right Ascension) to the sector by means of an iron rod (pipe) which turns in a ball-and-socket joint on the west axis of the declination fork. Near the joint this rod is bent through an angle of about 30°, so that the inclination of the rod to the tube can be varied through an angle of 180°. This rod runs through and can be clamped to a collar on the sector-frame near its outer extremity. The action of gravity on the sector-frame is the motive power for running the clock.

For large western hour-angles a shorter rod is screwed into the ball portion of the joint, in place of the longer rod.

The advantages of this form of mounting are:

First.—The upper and lower ends of the hour-axis are mounted on separate piers, thus giving great stability to the axis.

Second.—The moving tube is continually supported and braced in five different directions, viz.: the two supports forming the declination axis, the two supports given by the fork for clamping in declination, and the right ascension rod running to the sector.

Third.—The great radius of the sector diminishes the errors due to irregularities in the running of the clock.

The driving-clock forms part of one of the LICK Observatory chronographs, and was placed at my disposal by Professor HOLDEN.

For experimenting, a number of ordinary double convex lenses, about four inches in diameter, and having focal lengths of from one to twelve feet, were procured. All of these surfaces gave, by reflection, either blurred, distorted, or multiple images when placed in the best position on the axis of the eighteen-inch

mirror used as a Cassegrainian. In the work of refiguring the surface of one of these lenses, which gave an equivalent focal length of about eighty feet, I found it indispensable to have some convenient and rapid means for adjusting both the large and secondary mirrors. Accordingly, three longitudinal slots were cut in the tube, through which the three thin steel blades which support the secondary mirror project. These are fastened to wooden rods which run to the eye-end of the tube, where, by simply turning a hand-wheel, a slow motion towards or from the observer can be given to any one of the three supports of the secondary mirror.

The pan containing the large mirror is supported at three equidistant points by thumb-screws which pass through the lower (closed) end of the tube. By turning these screws the inclination of the large mirror can be changed at will.

The first surface figured required many hours of local polishing, the mirror (secondary) being tested on celestial objects at intervals, until the rays reflected from the large mirror were all brought to the same focus. To test the photographic advantages of this system, one of the most difficult of the celestial objects, giving the finest details for testing—the planet *Saturn*, —was photographed, with exposures varying from 1^s to 15^s. The character of the results obtained at once showed that much larger images than those corresponding to a focal length of eighty feet could be advantageously photographed.

Accordingly, I at once commenced correcting another surface which gives an approximate focal length of 250 feet. Patient polishing and repeated testing in the telescope resulted in a surface which gives even better images than the first one figured. The surfaces were all silvered by FOUCAULT'S process.

On the trial negatives *Saturn's* outer ring is something over six-tenths of an inch in diameter. The difference in brightness of the outer and inner rings, the shadow of the planet on the rings, the shadow of the ring on the planet, the crape ring, the belts on the planet, are all shown on the photographs.* At present the instrument is mounted in the open air, so that, in spite of the rigidity of the parts, the effect of the wind, plainly seen in the slightly shifting image on the ground glass, is such that the best results can only be expected after the instrument is

* Some of these trial photographs were exhibited at the meeting.

inclosed in a building. Until this is done it is inadvisable to make another secondary reflector giving still larger images.

I hope in a future number to give some photographic illustrations of celestial objects taken with this instrument, together with a view of this telescope.

With this particular mounting, the observations are restricted to objects having less than 70° declination. There is, however, no reason why the same form of mounting should not be used for all declinations; for, by simply lengthening the cradle in which the telescope swings to a little more than one-half of the length of the tube, the desired end is obtained.

Since the work on this telescope was commenced, a number of articles (by Mr. COMMON and others) have appeared, on what has been called a *skew* Cassegrainian telescope. It is safe to say that no large reflector used in this way will ever give as good results for full aperture as it would with its axis coinciding with the optical axis of the telescope. In the April number of the *Monthly Notices* of the Royal Astronomical Society, one observer (Mr. BROOKS) goes so far as to say: "I would here call attention to the fact that the correction of distortion caused by the tilting of the large speculum can be corrected by the proper tilting of the small flat mirror, as well as if it were convex." Now, it can easily be demonstrated that the image reflected from a plane mirror will have precisely the same form (neglecting reversals) as that which would be formed if the rays were allowed to come to a focus without secondary reflection; that is, the form of the image remains unchanged whatever the inclination of the plane mirror may be. A distorted image cannot be corrected by reflection from a plane surface; and it would seem that only by a happy accident could the distorted image from a large surface be completely corrected by reflection from a second curved surface.

I wish to state that this telescope was practically finished before Mr. CROSSLEY presented his great reflector to the LICK Observatory—a rather fortunate circumstance, for otherwise I should probably not have felt sufficiently encouraged to undertake the work of constructing the present instrument. With the exception of the clock, all the work was done by individuals connected with the LICK Observatory. Mr. MACDONALD, our foreman of the Observatory employees, and Mr. BANE, our carpenter, were especially active and efficient. Professor HOLDEN placed the resources of the Observatory at my disposal.